Photo credit: Luminaire Testing Laboratory

LED Measurement Series:

Luminaire Efficacy

The use of light-emitting diodes (LEDs) as a general light source is forcing changes in test procedures used to measure lighting performance. This fact sheet describes the concept of luminaire efficacy and the technical reasons for its applicability to LED-based lighting fixtures.

Lighting energy efficiency is a function of both the light source (the light "bulb" or lamp) and the fixture, including necessary controls, power supplies and other electronics, and optical elements. The complete unit is known as a luminaire.

Traditionally, lighting energy efficiency is characterized in terms of lamp ratings and fixture efficiency. The lamp rating indicates how much light (in lumens) the lamp will produce when operated at standard room/ambient temperature (25 degrees C). The luminous efficacy of a light source is typically given as the rated lamp lumens divided by the nominal wattage of the lamp, abbreviated lm/W. The fixture efficiency indicates the proportion of rated lamp lumens actually emitted by the fixture; it is given as a percentage. Fixture efficiency is an appropriate measure for fixtures that have interchangeable lamps for which reliable lamp lumen ratings are available.

However, the lamp rating and fixture efficiency measures have limited usefulness for LED lighting at the present time, for two important reasons:

1) Guidelines for rating the luminous flux of LED devices and arrays have not yet been adopted as industry standard test procedures in the U.S.[1]
2) The luminaire design and the manner in which the LEDs are integrated into the luminaire have a material impact on the performance of the LEDs.

These two issues are discussed in greater detail below. Given these limitations, how can LED luminaires be compared to traditional lighting technologies? As an example, the table below compares two recessed downlight fixtures, one using a 26-watt CFL and the other using an array of LEDs. The table differentiates data related to the light source and data resulting from actual luminaire measurements. Luminaire photometry shows that in this case the LED fixture is drawing about the same wattage as the CFL fixture, but providing less than half the lumens. This example is based on a currently available, commercial-grade, six-inch diameter downlight. LED downlight performance is expected to continue to improve rapidly.

Example: Comparison of CFL and LED Downlight Luminaires

	CFL	LED
Light Source		
Lamp lumen rating	1800 lm	
Light source wattage	26 W	*3 W*
LED manufacturer declared "typical luminous flux"		*~100 lm per LED**
Number of lamps/LEDs per fixture	1	10
Luminaire Measurements		
Luminaire lumens	1062 lm	475 lm
Measured luminaire wattage	26 W	28 W
Fixture efficiency	59%	
Luminaire efficacy	40 lm/W	17 lm/W

Items in *italics* are not based on industry standard test procedures as published by ANSI/IESNA.
*Depends on specific LED used. Estimate is based on "typical luminous flux" declared by LED manufacturer on the product datasheet, which assumes 25°C LED junction temperature.

No LED rating standard. Traditional light sources (incandescent, fluorescent, and high-intensity discharge) are rated for luminous flux according to established test procedures. In

[1] The International Lighting Commission (CIE) has published a revised technical report, "Measurement of LEDs" CIE 127:2007, which describes procedures for measuring total and partial luminous flux of individual LEDs. These have not been adopted as industry standard test procedures in the U.S. to date.

Terms

Photometry – the measurement of quantities associated with light, including luminance, luminous intensity, luminous flux, and illuminance.

Integrating sphere – a device that enables geometrically total luminous flux to be determined by a single measurement. The usual type is the Ulbricht sphere with associated photometric equipment for measuring the indirect illuminance of the inner surface of the sphere.

Goniophotometer – an apparatus for measuring the directional light distribution characteristics of light sources, luminaires, media, and surfaces. Goniophotometry can be used to obtain total luminaire flux (lumens) and efficacy (lumens/watt), but not the color metrics (chromaticity, CCT, and CRI).

Spectroradiometer – an instrument for measuring radiant flux (visible and non-visible) as a function of wavelength. Visible radiation measurements can be converted into luminous intensity (candela) and flux (lumens).

Lamp or light source – a generic term for a device created to produce optical radiation.

Luminaire – a complete lighting unit consisting of a lamp or lamps and ballast(s) (when applicable) together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

contrast, there is no industry standard test procedure for rating the luminous flux of LED devices or arrays. LED light output estimates (as reported on manufacturer datasheets) are typically based on a short (millisecond) pulse of power applied to the LED chip, with junction temperature held at 25 degrees C. This pulse testing is done when the chips are still on the production line, without heat sinks attached. Running them any longer would risk damage. LED manufacturers usually list "minimum" and "typical" luminous flux on their product datasheets. While "typical" in the electronics industry is understood to represent the statistical mean of the production sample tests, the test conditions have not been standardized through ANSI/IES test procedures.

Impact of luminaire design. For all light sources, there is a difference between rated luminous flux of the lamp and actual performance in a luminaire. However, traditional light sources installed in luminaires operate relatively predictably because the performance of traditional light sources in a wide range of luminaire types, applications, and use conditions is well documented and understood. LED technology is at a far earlier stage of development, so experience and documentation of performance within luminaires is lacking. The efficiency of LEDs is very sensitive to heat and optical design, which increases the relative importance of luminaire design.

Ensuring necessary light output and life of LEDs requires careful thermal management, typically requiring the use of the fixture housing as a heat sink or at least as an element in the heat removal design. Luminaires therefore have a fundamental and typically large effect on the luminous flux produced by the LEDs, and on the rate of lumen depreciation over time. LED "drop-in" replacement lamps, such as Edison-based reflector lamps or MR-16 replacements, are in theory designed to provide the necessary heat sinking for the LEDs, but given their installation in fixtures not specifically designed for LEDs, good heat management will be a challenge.

In summary, luminous flux – and by extension, luminous efficacy – must be measured at the luminaire level for two primary reasons: 1) standard test procedures for rating luminous flux of LED devices and arrays have not yet been adopted, 2) the amount of light emitted by a fixture cannot be predicted reliably based on available information about LED devices and fixtures. The lighting industry has adopted luminaire efficacy as the preferred measure of LED performance, as evident in the development of a new test procedure based on this approach.

New Test Procedure: LM-79

The lighting industry looks to the Illuminating Engineering Society of North America (IESNA) for lighting measurement test procedures. These test procedures are designated "LM" for lighting measurement, followed by an ordinal number, and the year of adoption or revision. They are developed by the IESNA Testing Procedures Committee, whose members include representatives of industry, research institutions, and testing laboratories.

The draft document entitled "IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products," designated LM-79, is currently under review by a joint IESNA-ANSI committee on SSL. Key elements of the document include:

- Covers fixtures incorporating light sources as well as light sources used for fixtures (e.g., LED retrofit products).
- Provides test procedures for photometric measurements using an integrating sphere, goniophotometer, and spectroradiometer.
- Photometric information measured may include: total luminous flux (lumens), luminous intensity (candelas) in one or more directions, chromaticity coordinates, correlated color temperature (CCT), and color rendering index (CRI).
- Electrical information measured includes: current, voltage, and power.
- Directs products to be "seasoned" by burning for 100 hours at rated electrical conditions, specified ambient temperature, and specified burning position before testing.
- Further, products must be stabilized until they reach thermal equilibrium before testing.

The new test procedure is expected to be finalized and published by the IESNA in 2007.

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For Program Information:

Kelly Gordon
Pacific Northwest National Laboratory
Phone: (503) 417-7558
E-mail: kelly.gordon@pnl.gov

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